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ANALYSIS OF EFFECTIVENESS AND COSTS OF RETROFIT EMISSION CONTROL SYSTEMS FOR USED MOTOR VEHICLES. VOLUME VI. ADDENDUM FOR DURABILITY TEST

Olson Laboratories, Incorporated
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ANALYSIS OF EFFECTIVENESS AND COSTS of RETROFIT EMISSION CONTROL SYSTEMS for USED MOTOR VEHICLES

volume V I

Addendum for Durability Test

prepared under
EPA Contract 68-04-0038

by
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In Association With Northrop Corporation

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for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air Programs
Division of Emission Control Technology
2565 Plymouth Road
Ann Arbor, Michigan 48105

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NOTICE

This report was prepared for the United States Environmental Protection Agency by Olson Laboratories, Inc. pursuant to an Environmental Protection Agency contract to evaluate automotive emission control retrofit methods. The information presented in this report in no way represents any endorsement or warranty by either the contractor or the United States government of any specific device reported on; nor does it represent any conclusion about the merits of any specific device which was not evaluated. The report is based on the contractor's evaluation of laboratory data developed under the contract, retrofit developer supplied data, and government furnished data when available. The information furnished herein is believed accurate and current as of May 1972.

FOREWORD

The Environmental Protection Agency, as Administrator of the Clean Air Amendments Act of 1970, is required to assist States and air pollution control agencies in meeting national ambient air quality standards and mobile or stationary source emission standards, by issuing information on control techniques. Contract 68-04-0038 was performed with the Office of Air Programs, Division of Emission Control Technology, to determine what emission control techniques are feasible for retrofit to used cars, considering emission reduction effectiveness, costs, effect on vehicle performance, and the facilities and labor skills required for retrofit device installation and eventual maintenance and inspection. This report documents the results obtained, the pertinent data upon which the results are based, the techniques of test and analysis, and the recommendations for future programs to implement the results. The report consists of the following six volumes:

I. Program Summary: Highlights the principal program results and conclusions as to the overall feasibility of retrofit methods for vehicle emission control. Provides guidelines for the evaluation of retrofit approaches and the implementation of control programs.

II. System Descriptions: Documents the physical, functional, and performance characteristics of the candidate retrofit methods and their installation requirements and costs.

III. Performance Analysis: Documents the relative effectiveness and costs of retrofit methods, the techniques of analysis and testing, and the assumptions and rationale upon which the analysis was based.

IV. Test and Analytical Procedures: Documents the approach to the overall program objectives and the tasks and procedures implemented to meet the objectives.

V. Appendices: Documents the raw data obtained from retrofit development sources and data of overall applicability to the report.

VI. Addendum for Durability Tests: Documents the results of 25,000-mile durability tests on four representative retrofit devices.

ACKNOWLEDGMENTS

This program was conducted under the direction and with the assistance of Dr. Jose L. Bascunana, Project Officer of the Environmental Protection Agency. Emission Control Technology, Inc., provided the methodology for performance analysis under a subcontract agreement with Olson Laboratories, Inc.

The accomplishment of this program was made possible by the cooperation and assistance of the many developers and manufacturers of retrofit devices. Their contribution of coordination time, data, and retrofit device hardware is very much appreciated.

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CONTENTS

Section			Page
	FOREWORD		iii
	ACKNOWLEDGEMENTS		iv
1	SUMMARY AND CONCLUSIONS OF DURABILITY TESTS		1-1
	1.1	Exhaust Test Results	1-2
	1.2	Effects of Device and Vehicle Operation	1-3
	1.3	Conclusions	1-5
2	INTRODUCTION		2-1
	2.1	Background	2-1
	2.2	Objectives	2-1
3	DURABILITY TEST PROGRAM		3-1
	3.1	Test Vehicles	3-1
	3.2	Description of Devices	3-1
	3.3	Vehicle Preparation and Maintenance	3-3
	3.4	Retrofit Device Installation and Maintenance	3-3
	3.5	Mileage Accumulation	3-3
	3.6	Emission Test Procedures	3-6
4	DURABILITY TEST RESULTS		4-1
	4.1	Exhaust Test Results	4-1
	4.2	Fuel and Oil Consumption	4-11
	4.3	Effects on Device and Vehicle Operation	4-15
Appendix			
A	Device and Vehicle Repairs and Maintenance		A-1

ILLUSTRATIONS

Figure		
3-1	Durability Test Route	3-5
4-1	The Effect of Mileage Accumulation on Air Bleed to Intake Manifold Retrofit Control System (Device 1, Car 4)	4-4
4-2	The Effect of Mileage Accumulation on the Catalyst Converter with Vacuum Advance Disconnect (Device 96, Car 21; No lead fuel used for mileage accumulation.)	4-6
4-3	The Effect of Mileage Accumulation on the Catalyst Converter with Vacuum Advance Disconnect (Device 96, Car 22;One tank of leaded premium fuel added at 2500 mile intervals.)	4-8

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SECTION 1

SUMMARY AND CONCLUSIONS OF DURABILITY TESTS

Volume VI provides data on five uncontrolled vehicles retrofitted with exhaust emission control devices to show the effect of mileage accumulation on exhaust emission reduction, driveability and safety, maintenance and inspection requirements, and device and vehicle reliability.

The effect of mileage accumulation on exhaust emissions was measured on four retrofit devices over a 25,000 mile interval. The four retrofit devices which had received up to 18 tests during the retrofit test program are identified as follows:

Device 1 (1)	Air Bleed to Intake Manifold
Device 96	Catalyst Converter with Distributor Vacuum Advance Disconnect (tests were conducted on 2 cars operated with unleaded fuel, but in one of the 2 cars one tank of leaded premium fuel was added every 2500 miles to measure the effect of an occasional exposure to leaded gasoline).
Device 175	Ignition Timing Modification with Lean Idle Mixture Adjustment
Device 246	Speed-Controlled Exhaust Gas Recirculation (EGR) with Distributor Vacuum Advance Disconnect

The test vehicles were tuned to the auto manufacturer's specifications and then the exhaust emissions were measured in the baseline condition (without device) by the 1972 Federal Test Procedures (2). Following installation of the device, the test vehicle received exhaust emission tests at 0, 5000, 10,000, 15,000, 20,000, and 25,000 test miles. A 25,000 mile baseline exhaust emission test was conducted to measure the baseline variation with mileage. This test was conducted on the uncontrolled car with no other changes other than removing the retrofit device. However, the car was adjusted to the auto manufacturer's specifications, if they were different than those required by retrofit developer. Replicate exhaust emission tests were conducted at the 20,000 and 25,000 test mile intervals. The test vehicles accumulated the required 25,000 miles on an approved representative test route which included normal city, urban, and freeway driving. Due to program time constraints the vehicles were driven approximately six hours per shift, three shifts per day, seven days per week.

(1) The retrofit devices evaluated in the durability test program are identified by device number and are described in detail in Volume II of this report.

(2) Federal Register, Volume 35 Number 219, November 10, 1970.

1.1 EXHAUST TEST RESULTS

Air Bleed to Intake Manifold (Device 1): This device was installed in accordance with the developer's instructions. The air bleed to the intake manifold system essentially showed no reduction in HC and CO emission at the zero mile and 25,000 mile test interval. Shortly after the 20,000 test point the carburetor was inspected to determine the cause for the increase in CO levels during mileage accumulation. The crankcase blowby control system inlet was found to be plugged at the base of the carburetor which caused blowby to be routed to the air cleaner and in turn may have caused the higher CO and HC levels. The carburetor was cleaned and reinstalled which resulted in lower HC and CO emissions. No adjustments were made on the device. The vehicle then continued to accumulate mileage. Following the 25,000 mile retrofit device tests, readjustment of the device by the developer showed substantial CO reduction from the 25,000 mile baseline tests.

Based on the durability test events, it appears that this device is sensitive to adjustment to achieve the desired emission reduction. It would be desirable that the installation instructions be revised to ensure that the device is adjusted to produce the expected emission reductions, and to verify the installation result by measuring the HC and CO emissions with appropriate instrumentation.

Catalyst Converter with Distributor Vacuum Advance Disconnect (Device 96): The catalyst equipped vehicle which was operated entirely on lead free fuel showed a 79, 97, and a 35 percent reduction in HC, CO, and NOx emission levels at the 0 mile interval.

The test vehicle (car 21) deteriorated rapidly after 10,000 test miles as indicated by a decrease in oil mileage (625 miles/qt in the 0-10,000 mile interval down to an average of 120 miles/qt in the 10,000 to 20,000 mile interval). The mileage accumulation on this vehicle was terminated shortly after 20,000 test miles due to the heavy oil consumption, loss of power, smoking from the tailpipe, and loss of the catalyst from the right converter. Exhaust emissions were still being reduced from 49 to 67% for all three pollutants at the 20,000 mile test point. Inspection of the retrofit device at the termination point revealed that one converter had lost all of its catalyst due to the failure of the retaining screen. The excess burning of oil may have accelerated the activity of the catalyst causing the failure of the converter.

The second catalyst system which had an occasional tank of leaded fuel showed good emission reductions at the zero mile point, and at the 25,000 test mile interval (81% for HC, 94% for CO, and 47% for NOx at the zero mile interval, and 80% for HC, 80% for CO, and 30% for NOx at the 25,000 mile interval), even though the test vehicle had shown deterioration in baseline emission levels as compared to the 0 mile baseline test.

Ignition Timing Modification with Lean Idle Adjustment (Device 175): This device showed an emission reduction of 28 and 48% for HC and NOx at the zero mile point and, 8% for HC and 39% for NOx at the 25,000 mile test interval. The CO showed a reduction of 18% at the zero mile point and, an increase of 24% above the baseline tests at the 25,000 interval. Towards the end of the durability tests the test vehicle developed moderate misfire due to a partial device failure at high speed and heavy load especially when accelerating onto the freeway. (See Section 4.3).

Speed-Controlled Exhaust Gas Recirculation with Distributor Vacuum Advance Disconnect (Device 246): This device showed a 46 and 45% reduction in HC and NOx at the zero mile interval. Emission levels varied significantly throughout the mileage accumu-

lation phase, and showed only a 10% NOx reduction at the 25,000 mile interval. HC and CO emission levels showed an increase. HC and CO increases may be attributable to continued choke malfunction which was found to be inoperative and repaired six times during mileage accumulation. The EGR speed-controlled switch had to be replaced twice (See Section 4.3). Partial malfunction of the control switch operation may possibly explain the limited NOx reduction that was measured at the 25,000 test mile interval.

1.2 EFFECTS OF DEVICE AND VEHICLE OPERATION

The effects of the mileage accumulation on the operation of the device and the impact on vehicle reliability are presented in this section. Summary discussions of fuel and oil consumption, driveability and safety, and device reliability are included.

Fuel and Oil Consumption: Fuel consumption was measured during the 1972 CVS exhaust test conducted at each 5000 mile interval. Baseline fuel consumption tests were measured for comparison to the device tests at 0 and 25,000 miles. One fuel consumption test was conducted at the 0 mile interval and three tests were conducted at the 25,000 mile interval.

The fuel consumptions measured during the 1972 Federal emission tests (3 replicate tests, with and without device) at the 25,000 test mile interval can be compared with the similar measurements that were conducted on the retrofit fleet (the retrofit fleet refers to the twenty cars used for testing the eleven devices in the retrofit program). This comparison indicates that the durability and the retrofit fleet vehicle fuel consumption average changes were in agreement only for Devices 1 and 175. For Devices 96 and 246 there was inconsistency. The fuel consumption changes measured with the retrofit fleet cars would be more representative because of the larger number of tests and cars involved.

Road fuel consumptions were measured throughout the 25,000 miles with the device installed. No baseline road fuel consumption measurements were conducted prior to the device durability tests. Therefore, road fuel consumption comparisons (with and without device) cannot be made. Additional testing should be conducted to determine fuel consumption (of vehicles both with and without the device) for freeway driving, and to establish the statistical significance of the data.

In every case the gasoline mileage results measured during the CVS exhaust test were lower (less miles per gallon) than the average miles per gallon measured on the road during the previous 5000 mile interval. This could be explained by the freeway driving included in the durability test route. Vehicle degradation and tuneup related problems may have caused some of the gasoline mileage results to fluctuate and increase towards the end of 25,000 miles.

As mileage was accumulated, oil mileage measurements generally showed degradation for all five test cars. The lowest test vehicle odometer mileage at the start of the durability tests was 59,000 miles and the highest mileage at the end of the tests was 117,000 miles. The degradation in oil mileage for these used cars was expected. The oil mileage of car 22 degradated from 625 miles per quart down to 120 miles per quart and was terminated at 20,000 test miles due to loss of power, low compression and heavy smoking from the tailpipe.

Final inspection of the devices and all of the test data indicate that none of the retrofit devices which received the durability tests caused the degradation in oil consumption on these test vehicles. This degradation is normal for cars which have high odometer mileage.

Driveability and Safety: The durability test drivers were non-technical personnel and were not trained to monitor retrofit device driveability type problems such as those measured during the retrofit fleet tests using the AMA driveability procedure. However, the durability test drivers did maintain daily log sheets which were designed to record any vehicle anomalies related to performance and safety. These items were inspected on a daily basis by an OLI mechanic-technician. If mechanical problems (device or vehicle) were suspected during the driving period, the driver was instructed to return to the test facility for corrective maintenance. The mechanic-technician corrected and recorded the vehicle or device problem, and then the vehicle continued mileage accumulation. The durability drivers did not report any problems that would indicate unacceptable driveability.

No safety oriented problems to the vehicle or the occupants were observed throughout the durability tests for the four devices. As mentioned above, one catalyst converter (Device 196) failed prematurely but did not cause excessive unsafe temperatures to the vehicle.

Device Reliability: No device anomalies were observed on the air bleed to manifold system (Device 1) except for the installation problem discussed above in Section 1.1.

One catalyst converter (Device 96) failed prematurely at 20,000 test miles (see Section 1.1 above). The rapid deterioration and high oil consumption of the vehicle after 10,000 miles was believed to be the cause of the converter failure. On the second catalyst equipped vehicle, the air bypass valve (which diverts converter injection air to the atmosphere) was replaced twice during the durability tests, which may have been attributable to the mechanical design of the valve.

The ignition timing modification device partially failed and caused some ignition misfire problems after the alternator had failed (see Vehicle Reliability below).

The EGR speed control switch was replaced twice; once due to physical damage at a car wash, and the second time was due to a mechanical failure of the replacement. The EGR control valve contained only a light film of carbon appearing residue at the 25,000 mile test interval.

Vehicle Reliability: The blowby inlet to the base of the carburetor became plugged with blowby residue on car 4 which was equipped with the air bleed system (Device 1). This was definitely not a retrofit exhaust control device oriented problem and was not abnormal for a used vehicle with 110,000 miles.

Both catalyst equipped vehicles (Device 96) deteriorated considerably. The failure of one converter on car 21 was probably due to the high oil consumption of that car.

The catalyst system also included the use of vacuum advance disconnect which generally causes engine coolant to run hotter. However, the retrofit device did not cause any engine coolant overheating problems.

The ignition timing modification system (Device 175) retards the timing at low vehicle speeds. This system did not cause any engine coolant heating problems. At 23,500 miles the test vehicle (car 17) alternator failed. Coincidentally, the vehicle developed ignition misfire at heavy engine loads especially when accelerating onto the freeway. As instructed by the developer, the vehicle continued to accumulate mileage after the alternator was repaired. Following the 25,000 mile baseline and device emission tests, removal of the device eliminated the misfire without any other changes.

Final examination of the device by the developer revealed that two device diodes had failed which could have possibly been caused by the alternator failure. If the alternator failure was the cause of the device malfunction, then the device should be redesigned to prevent such failures in the event of vehicle electrical problems.

The exhaust gas recirculation system (Device 246) was equipped with a vacuum advance disconnect, and did not cause any engine coolant overheating problems. This car, however, experienced chronic choke problems which required six repair actions.

1.3 CONCLUSIONS

The durability tests have shown data to substantiate the following conclusions.

- To ensure the emission reduction that can be obtained by a retrofit device, the vehicle should receive an emission inspection with appropriate HC, CO and NOx instrumentation at the time of retrofit installation and periodically thereafter. In addition, it is mandatory that all engine condition and tuneup items be properly maintained for lowest emissions and good driveability. One foregoing example discussed the installation of a device which showed no emission reduction at the time of installation. Had the installation instructions included the use of an HC and CO meter to verify emission reductions, the installation of this device may have achieved the expected emission reduction.

  Appropriate inspection instrumentation, procedures, and frequency of inspection should be determined for the particular retrofit devices. The severity of the pollution control requirements should be considered. If the emission inspection measurements are not implemented, the potential for retrofit emission reduction will not be achieved. If a retrofit inspection program is not implemented, the actual emission reductions could only be determined by a statistical analysis of the results from a representative test fleet sample.

- No device oriented safety problems were observed during the durability tests.

- Auxiliary retrofit device components (such as air bypass valves on air injected catalyst systems and speed control switches on exhaust gas recirculation systems) can be failure prone with mileage accumulation. Good mechanical design with adequate reliability tests are prerequisites for reliable retrofit device operation.

- Retrofit device installation and operation on used vehicles with high oil consumption or other abnormal mechanical conditions may not be appropriate. For example, certain types of retrofit devices could be rendered ineffective as a result of installation on such vehicles. One example of this was the failure of the catalytic converter believed to be caused by excessive oil consumption. Another example of this was the choke system which required six repair actions.

SECTION 2

INTRODUCTION

2.1 BACKGROUND

The durability report is Volume VI to the retrofit final report entitled "Analysis of Effectiveness of Retrofit Emission Control Systems for Used Motor Vehicles." A durability vehicle is defined here as a vehicle that is driven on an approved test route for a specified amount of miles to measure the effect of mileage accumulation on the performance of a retrofit emission control system.

2.2 OBJECTIVES

The purpose of the durability test program was to determine the impact of retrofit device performance on vehicle operation over a 25,000 test mile interval. The test parameters included the effects of exhaust emission reduction and deterioration, driveability, safety, device and vehicle reliability, and maintenance and inspection requirements.

SECTION 3

DURABILITY TEST PROGRAM

3.1 TEST VEHICLES

The five vehicles for the durability phase tests were chosen as being approximately representative of the used car population which were not originally equipped with exhaust control devices. Complete test vehicle selection criteria are outlined in Volume IV of the retrofit final report.

Table 3-1 identifies the durability test vehicles.

3.2 DESCRIPTION OF DEVICES

The devices chosen for the durability tests were the same devices that received up to 18 emission and driveability tests during the retrofit test program.

The retrofit devices evaluated in the durability test program are identified by device number and are described in detail in Volume II of this report.

Device 1. Air Bleed to Intake Manifold: An air bleed to intake manifold system which operates by metering filtered air into the induction system of the engine below the carburetor at medium and high manifold vacuum as during idle or deceleration.

Device 96. Catalytic Converter with Distributor Vacuum Advance Disconnect: This device consists of a charged canister of catalyst pellets primarily designed for controlling unburned hydrocarbons and carbon monoxide, and is mounted in the exhaust system near the exhaust manifold. Distributor vacuum advance disconnect is also used to achieve reductions in oxides of nitrogen. Installation on uncontrolled vehicles require an air pump to inject air into the vehicle exhaust system which provides oxygen to the converter for maximum emissions reduction. This retrofit system also includes an air bypass valve which diverts the injected air to atmosphere if maximum safe converter temperatures are exceeded.

Device 175. Ignition Timing Modification with Lean Idle Adjustment: This device is an ignition timing modification system which retards the timing at low speeds for the control of hydrocarbons and oxides of nitrogen emissions. Ignition control is accomplished by electronic regulation of the distributor signal and by regulation of the distributor vacuum advance mechanism. Both means of regulation retard the basic timing of the engine. Carbon monoxide is partially controlled by adjusting the carburetor idle to a "best lean" setting.

Device 246. Speed-Controlled Exhaust Gas Recirculation with Distributor Vacuum Advance Disconnect: This exhaust gas recirculation system device is intended to re-

Table 3-1. DURABILITY TEST VEHICLES

Vehicle No.	Device (1)	Vehicle Year/Model	CID	Odometer Zero Test Miles	License No.	(3) Fuel for Mileage Accumulation	Exhaust Emission Test Fuel
4	1	65 Chev Impala	327	86003	PJA 404	Premium	Indolene 30
17	175	65 Ford Ltd	390	59446	RPZ 845	Premium	Indolene 30
18	246	61 Chev Impala	283	83009	MSL 123	Premium	Indolene 30
21	96	65 Chev Impala	327	62552	PFR 197	Unleaded	Indolene Clear
22	96	65 Chev Impala	327	92313	PIU 532	Unleaded(2)	Indolene Clear

(1) The retrofit devices evaluated in the durability test program are identified by device number and are described in detail in Volume II of this report.

(2) One (1) tankfull premium grade gasoline (with lead) after each CVS exhaust emission test and repeated at 2500 mile intervals.

(3) Fuel for mileage accumulation purchased from service stations. Fuel composition is presented in Table 3-2.

duce all exhaust emissions, particularly oxides of nitrogen. Approximately 15 percent of the vehicle exhaust gas is recirculated to the intake manifold at vehicle speeds over 26 mph. Exhaust gas recirculation is terminated at speeds less than 12 mph. This system also incorporates vacuum advance disconnect at low speeds.

3.3 VEHICLE PREPARATION AND MAINTENANCE

The test vehicles used in the durability phase tests were subjected to an intensive screening inspection to minimize major mechanical failures during mileage accumulation. An overall inspection was conducted for safety related items such as tires, brakes, and alignment. The vehicle engine condition was inspected for excessive wear. Cars were selected having normal blowby flow rates within the fourth and seventh population decile (California Test Procedure and Criteria for Motor Vehicle Crankcase Emission Control). Cranking compression pressures were measured, and if cylinder pressures measured within a range of 10 psi of the automobile manufacturer's specifications, the car was acceptable. The engine condition criteria was to purchase vehicles in reasonable mechanical condition, and that would not require major engine repair during the durability test program. Carburetor malfunctions were determined by measuring the hydrocarbons and carbon monoxide emissions at idle and at 2500 rpm (free running). Ignition system condition was monitored with an ignition analyzer scope. Complete vehicle preparation procedures are outlined in Volume IV of this report.

After accepting the durability test vehicle, it was tuned to the auto manufacturer's specifications prior to retrofit device installation.

3.4 RETROFIT DEVICE INSTALLATION AND MAINTENANCE

Retrofit devices were installed in accordance with the retrofit developer's instructions and/or under the direct supervision of the retrofit developer's representative. During the durability tests, the vehicles were maintained as per the vehicle manufacturer's and the retrofit developer's specifications.

Daily visual inspection of each vehicle was conducted to observe any malfunction or deterioration of a device. Device anomalies as observed were referred to the project engineer and the retrofit developer. Corrective action was taken only if appropriate for the durability program. Vehicle repairs such as water pump failures, tires, and brakes were corrected as necessary during mileage accumulation.

3.5 MILEAGE ACCUMULATION

Test Route: Mileage was accumulated on each test vehicle driven over a 32 mile durability test route in the Anaheim, Fullerton, and Santa Ana, California area. The route was designed to maintain an average vehicle speed of 30-35 mph.

The durability test route shown in Figure 3-1, is patterned after the California LA-2 durability test route and contains several types of driving modes as shown in the following table:

DURABILITY TEST ROUTE DRIVING MODES

Driving Mode	Maximum Speed Limit	Approximate Time in Mode, %
Freeway	65 miles per hour	30
Suburban	45 miles per hour	40
City	25 miles per hour	15
Residential	35 miles per hour	15

Driving Schedule: Durability test driving was conducted on an accelerated basis by operating the vehicles for six hours per shift, three shifts each work day, seven days per week. Due to the time limit constraint on this program, each durability test vehicle was also driven on a 100 mile freeway route three times each day.

Fuel Requirements: The vehicles which were equipped with the Air Bleed (Device 1), Ignition Timing Modification (Device 175), and the Exhaust Gas Recirculation (Device 246) retrofit systems used premium grade gasoline purchased at local service stations for mileage accumulation. As requested by the developer, both catalyst system (Device 96) equipped vehicles used unleaded grade gasoline purchased at local service stations for mileage accumulation. At each 2500 test mile interval, one tankfull of premium gasoline (with lead) was used on one of the catalyst equipped vehicles to measure the effect (if any) of an occasional tankfull of leaded fuel for the performance of the catalyst catalyst. The technical data for the unleaded and premium gasolines used for mileage accumulation on the catalyst systems are presented in Table 3-2.

Table 3-2. MILEAGE ACCUMULATION GASOLINE TYPICAL PROPERTIES (1)

	Unleaded Grade	Premium Grade (With Lead)
Octane Number		
o Research	91.7	100.1
o Motor	82.8	91.8
Hydrocarbon Composition, Vol %		
o Aromatics	30	36
o Olefins	7	8
o Saturates	63	56
Lead Content, Grams per Gallon	0.02 - 0.14	2.97
Phosphorus	None Added	None Added

(1) Average composition for December 1971, and January and February 1972. Samples taken from several service stations and analyzed by a major oil company supplier in Orange County, California.

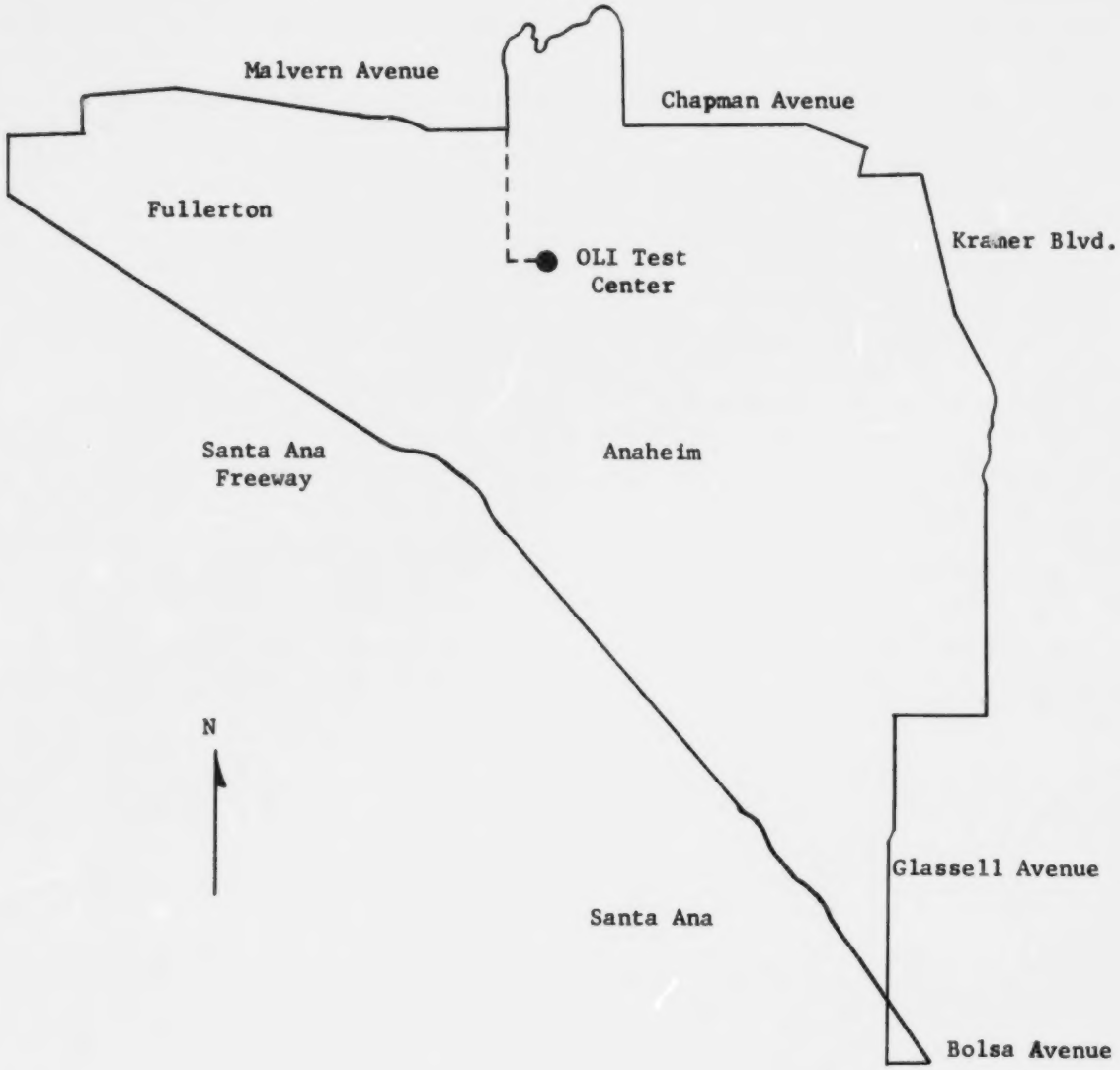


Figure 3-1 Durability Test Route Orange County, California

3.6 EMISSION TEST PROCEDURES

A baseline (after tuneup) CVS emission test was conducted on each durability test vehicle in accordance with the 1972 Federal Exhaust Emission Test Procedures (1). Fuel consumption was also measured during the CVS emission test. The retrofit device was then installed, and the vehicle was tested again to establish the zero test mile device emission levels.

Mileage was accumulated on the durability test cars and CVS emission and fuel consumption tests were conducted at 5000, 10,000, 15,000, 20,000, and 25,000 miles with the retrofit device in operation. Single tests were conducted at the 0, 5000, 10,000 and 15,000 mile intervals. Due to the variability of the emission test results of preceding tests, the 20,000 mile durability CVS emission tests were conducted in duplicate (one car received duplicate tests beginning at 15,000 test miles). The 25,000 mile durability CVS and the final baseline emission tests were conducted in triplicate. When necessary, special additional CVS emission tests were conducted to diagnose vehicle or device anomalies.

(1) Federal Register, Volume 35, Number 219, November 10, 1970

SECTION 4

DURABILITY TEST RESULTS

The results of the mileage accumulation are presented in this section, and include discussion on the exhaust emission, fuel consumption and oil consumption test results. The effects of the device on vehicle operation are also discussed in terms of driveability and safety, and device and vehicle reliability.

4.1 EXHAUST TEST RESULTS

The exhaust emission data for each vehicle at 5000 mile intervals are presented in Table 4-1.

Data plots of the hydrocarbons, carbon monoxide and oxides of nitrogen emission data versus mileage accumulation for each durability vehicle are presented in Figures 4-1 through 4-5.

Device 1. Air Bleed to Intake Manifold

The air bleed device was initially installed in accordance with the retrofit developer's instructions. With the engine warmed up, the device was adjusted to cause a 2.5 inch of mercury manifold vacuum drop from the baseline (W/O device) manifold vacuum. The idle RPM was reset to the auto manufacturer's specifications.

The emission reduction at the zero and 25,000 mile intervals were:

EMISSION REDUCTION, PERCENT
Air Bleed to Intake Manifold, Car 4

	Zero Miles	25,000 Miles Avg. of 3 Tests With and Without Device	25,000 Miles Avg. of 3 Tests Without Device and 1 Test With Device (1)
HC	0.5	6.5	-7.1
CO	-2.2	6.5	63.6
NOx	-15.7	20.9	8.9

(1) Original device reinstalled and adjusted by developer.

Table 4-1. Exhaust Emission Data of Retrofit Durability Test Vehicles 1972 Federal Test Procedure

All Emission Results in Grams/Mile

Durability Emission Test Results

Device No.(1)	Description	Vehicle No.	Odometer, Miles: 0 Mile Test	Odometer, Miles: 25,000 Mile Test	Exhaust Pollutant	Baseline, Zero Test Miles	Device, Zero Test Miles	Device, 5,000 Test Miles	Device, 10,000 Test Miles	Device, 15,000 Test Miles: Test 1	Device, 15,000 Test Miles: Test 2	Device, 20,000 Test Miles: Test 1	Device, 20,000 Test Miles: Test 2	Device, 25,000 Test Miles: Test 1	Device, 25,000 Test Miles: Test 2	Device, 25,000 Test Miles: Test 3	Baseline, 25,000 Test Miles: Test 1	Baseline, 25,000 Test Miles: Test 2	Baseline, 25,000 Test Miles: Test 3
1	Air Bleed to Intake Manifold	4	86003	111066	HC	7.91	7.87	10.00	9.92	10.98		10.45	9.75	6.73	6.79	6.38	7.25	7.24	6.79
					CO	80.01	81.75	113.06	97.98	111.27 (2)		133.33	126.42	45.98	47.88	42.68	42.32	47.56	56.22
					NO_x	2.35	2.72	2.38	2.81	3.88		3.77	3.40	3.79	3.38	3.71	4.64	5.38	3.76
96	Catalyst Converter with Vacuum Advance Disconnect (Unleaded Fuel, only)	21	62552	82620 (3)	HC	9.00	1.91	0.87	5.06	5.93		5.70	5.55				16.99	Final Baseline, 20,000 Miles (3)	
					CO	92.10	2.65	17.48	58.48	97.17 (2)		103.05	82.60	Final Device Tests, 20,000 Miles (3)			210.56		
					NO_x	3.67	2.39	1.93	1.08	0.61		0.49	0.90				1.35		
96	Catalyst Converter and Vacuum Advance Disconnect (Unleaded fuel with one Tank of Leaded Fuel at 2500 Mile Intervals)	22	92313	117361	HC	7.91	1.53	1.27	3.03	2.96		5.01	5.39	5.97	4.56	5.08	28.04	25.67	25.55
					CO	64.94	4.15	4.80	13.12	6.78 (2)		18.58	19.42	23.84	11.51	15.43	90.11	82.26	86.97
					NO_x	4.27	2.25	2.39	2.29	4.20		2.40	2.24	2.32	2.84	2.32	3.60	3.50	3.57
175	Ignition Timing Modification with Lean Idle Adjustment	17	59446	84503	HC	8.08	5.83	6.20	8.89	8.00	8.31	9.90	209.87	7.92	7.81	8.13	8.18	9.14	8.70
					CO	125.45	103.45	144.80	217.47	170.78	170.51	10.33	214.71	178.87	176.83	176.05	142.08	146.64	140.82
					NO_x	3.35	1.74	0.82	1.27	1.83	1.44	1.19	0.91	1.30	1.23	1.36	1.86	2.08	2.41
246	Exhaust Gas Recirculation with Vacuum Advance Disconnect	18	83009	108081	HC	16.08	8.68	9.38	5.43	16.07		3.50		5.73	6.79	8.14	6.82	6.76	6.43
					CO	85.86	92.98	173.65	62.40	290.57 (2)		28.98 (2)		61.04	71.14	90.43	51.52	53.91	37.99
					NO_x	1.46	0.81	0.44	1.44	0.34		2.30		3.48	1.52	1.74	2.38	2.60	2.55

Additional Tests for Diagnostic Purposes

Device No.(1)	Description	Vehicle No.	Test Miles	Exhaust Pollutant	Device Test (See Notes): Test 1	Device Test (See Notes): Test 2
1	Air Bleed to Intake Manifold	4	21427 Before Carburetor Cleaning	HC	9.97 (4)	(2)
				CO	98.95	
				NO_x	3.64	
			21427 After Carburetor Cleaning	HC	6.72 (5)	6.74 (5)
				CO	46.81	43.14
				NO_x	3.35	4.93
			25,000	HC	6.17 (6)	7.59 (7)
				CO	16.64	17.70
				NO_x	3.26	4.18
96	Catalyst Converter with Vacuum Advance Disconnect (Unleaded Fuel, Only)	21	Test 1: 16764	HC	3.00 (8)	2.77 (8)
				CO	23.82	35.91
			Test 2: 16878	NO_x	1.93	1.97

NOTES: (See text for discussion)

(1) Identification of devices included in Volume V

(2) Replicate test not conducted

(3) Two tests with device and one baseline test conducted at 20,000 test miles. Mileage accumulation terminated shortly after 20,000 test miles

(4) Remove carburetor and inspect blowby inlet; reinstalled carburetor and conducted one CVS emission test

(5) Remove carburetor again and clean; reinstalled carburetor and conducted two CVS emission tests

(6) Replacement device installed and adjusted by developer

(7) Original durability device reinstalled and adjusted by developer

(8) Diagnosis for possible carburetor malfunction

The zero mile emission test results essentially showed no change as compared to baseline tests without a device. The reasons for not showing a reduction in emissions at the zero mile interval are unknown.

As mileage was accumulated the CO and NOx levels increased. HC levels increased up to the 5000 mile interval and then remained nearly constant through the 20,000 mile interval (Figure 4-1).

Shortly after the 20,000 mile interval, an inspection was conducted to determine the cause for the CO increase (see Figure 4-1). The carburetor was removed and inspected. Blowby deposits and residue had accumulated in the blowby inlet at the base of the carburetor and the inlet appeared to be plugged. The plugging of the blowby inlet to the carburetor was not caused by the retrofit device. This condition caused blowby to flow through the tube to the air cleaner, instead of through the PCV valve into the base of the carburetor. When blowby gases are routed to the carburetor air inlet, carburetor air-fuel mixtures are richer. The gradual increase in CO emission levels indicate that the carburetor may have gradually plugged up during the first 20,000 test miles. The carburetor was reinstalled and a CVS test was conducted prior to cleaning the carburetor at 21,427 test miles. The carburetor was removed again, cleaned and reinstalled. The idle CO was adjusted to the same baseline level measured at 0 test miles. As a result, the carburetor cleaning caused a decrease in HC and CO emission levels and an increase in NOx (see Figure 4-1). During these tests no retrofit device adjustments were made.

Following the 25,000 mile tests (retrofit and baseline), a replacement air bleed device was installed. The device was adjusted by the developer to cause the idle manifold vacuum to be reduced 3" Hg. The idle air-fuel mixture was also adjusted by the developer. Emission levels at idle of 500 ppm hydrocarbons and 0.2 percent carbon monoxide were measured with an Olson-Horiba Mexa 300 NDIR Exhaust Analyzer. Standard CVS emission tests were then conducted with the replacement device. The "replacement device" test caused a reduction in HC, CO and NOx levels from the 25,000 mile baseline test.

The air bleed device used in the durability test was reinstalled on the test vehicle and adjusted to cause an idle manifold vacuum drop of 2.5 inches of mercury. A standard CVS emission test with the original device was conducted. The emission results of the original air bleed device showed a 64% reduction in CO from the baseline results but a 7% increase was shown for HC. NOx decreased 9%.

In summary, the device was installed as per the developer's instructions at the zero mile interval. Since the replacement of the original device and readjustment by the developer at the 25,000 mile interval caused a reduction in CO, the device appears to be sensitive to adjustment to achieve the desired emission reduction.

Device 96. Catalyst Converter with Vacuum Advance Disconnect
(Unleaded fuel used for mileage accumulation)

Car 21 was operated entirely on no lead fuel throughout the mileage accumulation phase (see Table 3-2 for fuel composition).

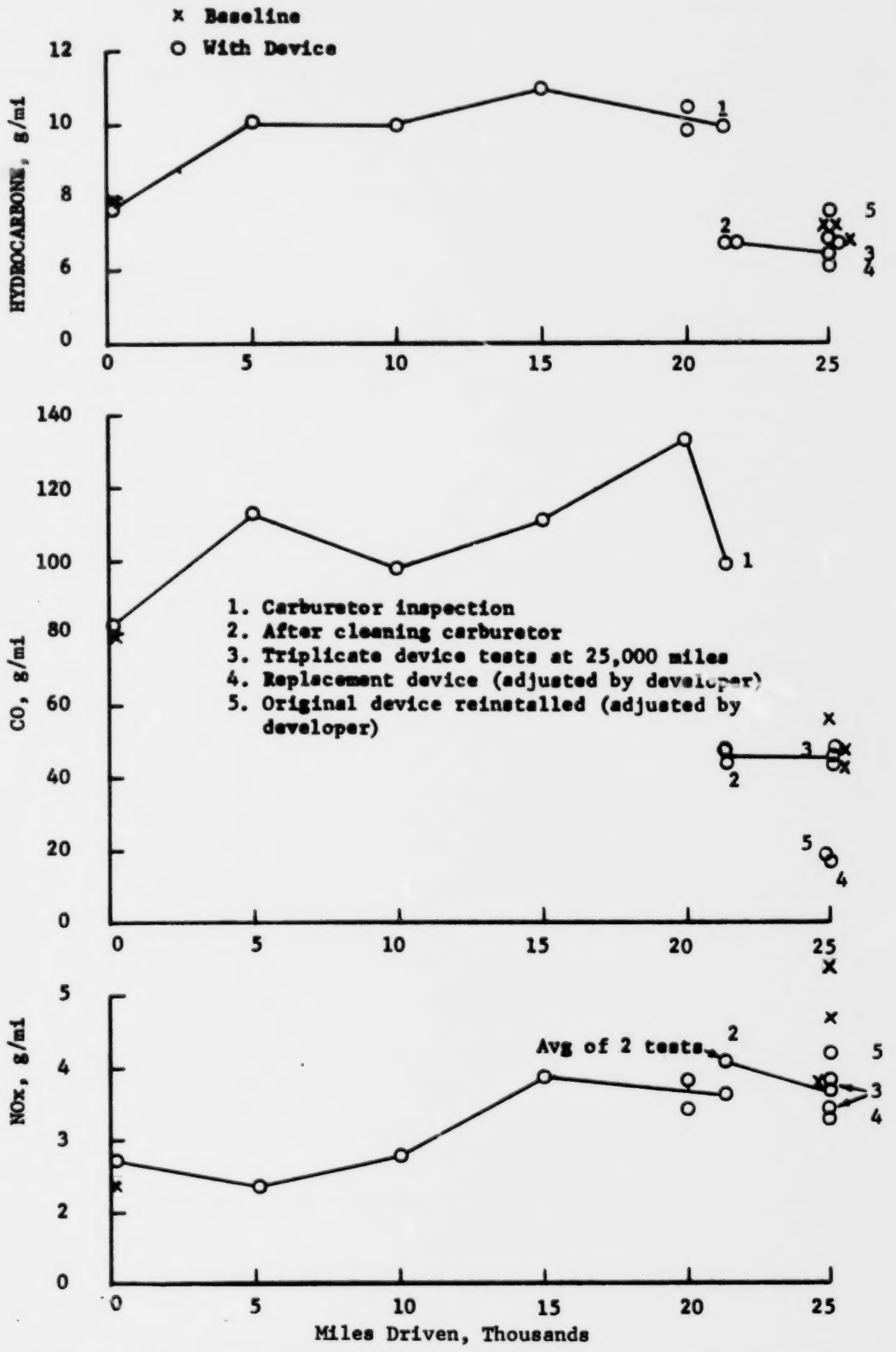


Figure 4-1. THE EFFECT OF MILEAGE ACCUMULATION ON AIR BLEED TO INTAKE MANIFOLD RETROFIT CONTROL SYSTEM (DEVICE NO. 1, CAR NO. 4)

The emission reductions from baseline were:

EMISSION REDUCTION - PERCENT

Unleaded Fuel - Catalyst Converter, Car 21

	Zero Miles	20,000 Miles Avg of 2 Tests with Device and 1 Test Without Device
HC	79	67
CO	97	56
NOx	35	49

Durability tests of car 21 were terminated at 20,000 miles. A summary of the events leading to termination of mileage accumulation is presented.

At 16,878 miles faulty carburetor operation was suspected as the cause for the high carbon monoxide emissions measured during the 15,000 mile CVS emission test (see Figure 4-2). The CO was 5.0% and the HC was 380 ppm measured by a Horiba Mexa 300 NDIR exhaust analyzer upstream of the catalytic converter while operating at 2500 rpm (neutral). The vehicle carburetor was dismantled and inspected. No blowby residue at the PCV inlet was found and the power valve circuit was operating in a normal manner. The fuel float levels were checked and found to be at manufacturer's specifications. An ignition analyzer showed no plug misfire. The distributor advance system (with the vacuum advance disconnect) was operating properly.

Both a rebuilt carburetor and a new carburetor were installed. Carbon monoxide levels remained at greater than 5.0% at 2500 rpm in neutral for both the new and rebuilt carburetors. The hydrocarbons were 350 ppm at 2500 rpm with the rebuilt carburetor. The rebuilt carburetor was left on the test vehicle for continued mileage accumulation. The original carburetor was installed on a privately owned 1965 Chevrolet and showed a CO level of 1.5% at 2500 rpm in neutral.

Oil mileage rates were 625 miles/quart for the first 10,000 miles of mileage accumulation. In the 15,000-20,000 mile interval the oil mileage decreased to 120 miles per quart indicating the vehicle engine was deteriorating at a very rapid rate (Table 4-2). Heavy smoke was being emitted from the tailpipe. Compression pressures also deteriorated with three cylinders between 30 and 70 psi at the 20,000 mile interval (Appendix A). Converter temperatures varied between 1200-1300°F during a freeway trip of 50 miles at the 18,000 test mile point.

Shortly after the device tests at 20,000 miles, both converters were removed from the vehicle and inspected. Eightly-seven percent of the catalyst was recovered from the left converter. No catalyst was recovered from the right converter due to a failure of the catalyst retaining screen. The amount of catalyst that could have already been lost (if any) at the 20,000 mile test point is not known. Photographs of the retaining screen failure are presented in Figure 4-6. Because of the deterioration of the vehicle and the loss of catalyst in the left converter, the vehicle mileage accumulation was terminated at this time.

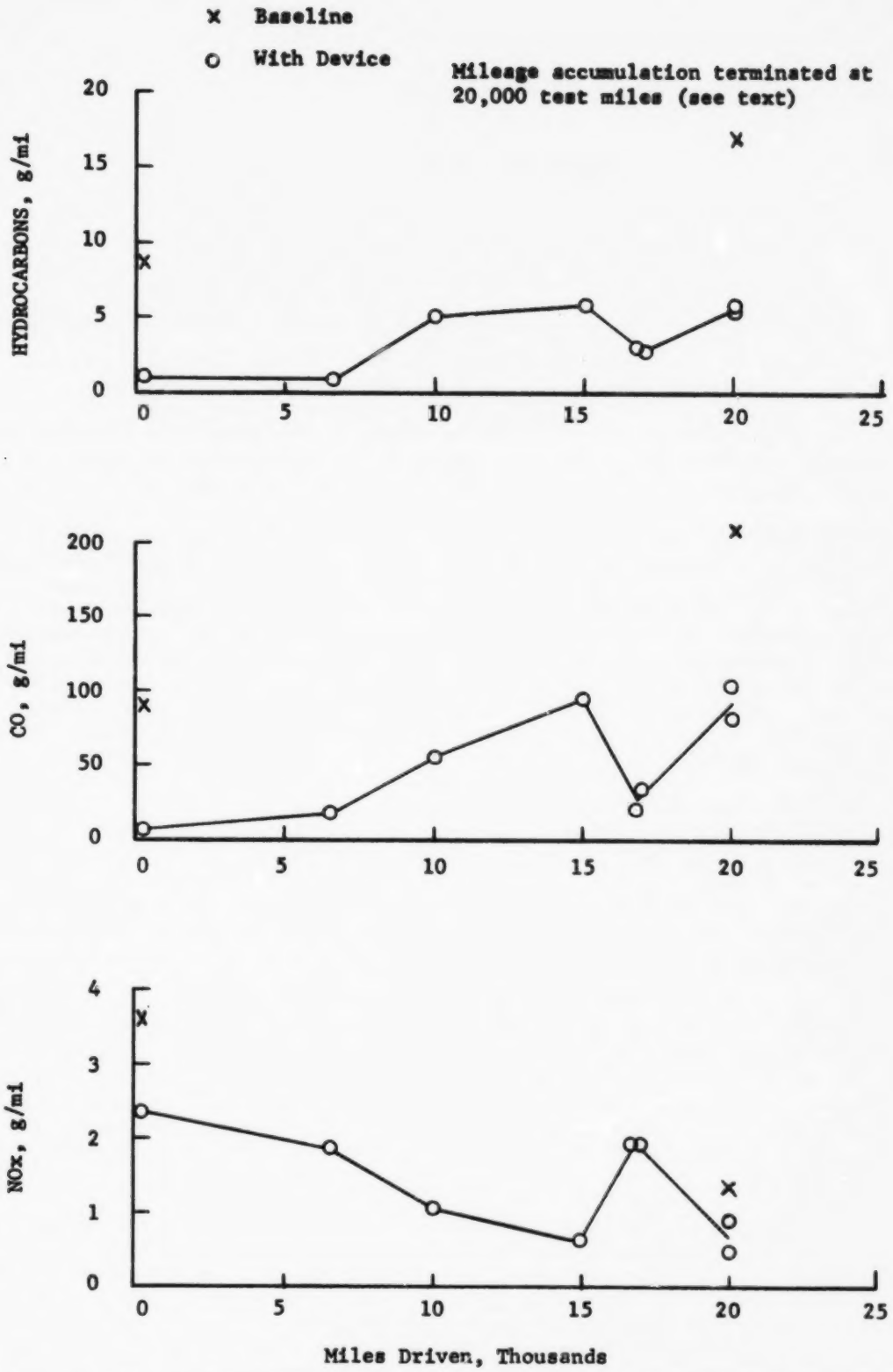


Figure 4-2. THE EFFECT OF MILEAGE ACCUMULATION ON THE CATALYST CONVERTER WITH VACUUM ADVANCE DISCONNECT (DEVICE 96, CAR 21) NO LEAD FUEL USED FOR MILEAGE ACCUMULATION

In summary, the vehicle deteriorated considerably in the 20,000 mile test interval as indicated by the baseline emission levels and the increased oil consumption (see Section 4-2). The excess burning of oil may have accelerated the activity of the catalyst causing a possible premature failure of the converter. However, the total exhaust emissions were still being reduced from 49 to 67% for all three pollutants.

The above discussion shows that the problems were vehicle related rather than device related.

Device 96. Catalyst Converter with Vacuum Advance Disconnect
(One tank of leaded fuel every 2500 miles)

Car 22 with the catalyst converter was normally operated with unleaded fuel (see Table 3-2 for fuel composition used during mileage accumulation).

A full tank of leaded premium fuel was added to the vehicle at 2500 mile intervals to simulate accidental fueling of the vehicle with leaded fuels. Leaded fuel was always added after the scheduled vehicle CVS emission test. The emission reduction results were:

EMISSION REDUCTION, PERCENT

Catalyst Converter, Car 22
One Tank of Leaded Fuel Every 2500 Miles

	Zero Miles (1 Test)	25,000 Miles Avg of 3 Tests
HC	81	80
CO	94	80
NOx	47	30

The results of the baseline and device tests show that the average emission reduction was maintained throughout the 25,000 mile durability test. The absolute HC and CO levels gradually increased but the net average reduction remained essentially constant (Figure 4-3). It appears that a tank of leaded fuel, added at 2500 mile intervals, did not significantly change the emission levels during the 25,000 mile durability tests.

The baseline emission levels at the 25,000 mile interval indicated that the vehicle engine condition had deteriorated. Baseline, HC emissions substantially increased about 18 grams/mile between the 0 and 25,000 mile point, and the CO levels increased approximately 20 grams per mile. The large HC increase may have been attributable to high blowby rates caused by one low cylinder. Compression pressures ranged from 150 to 180 psi but the low cylinder was down to 30 psi.

In summary, the emission results show that the device was still capable of substantial emission reductions even through the test vehicle had deteriorated.

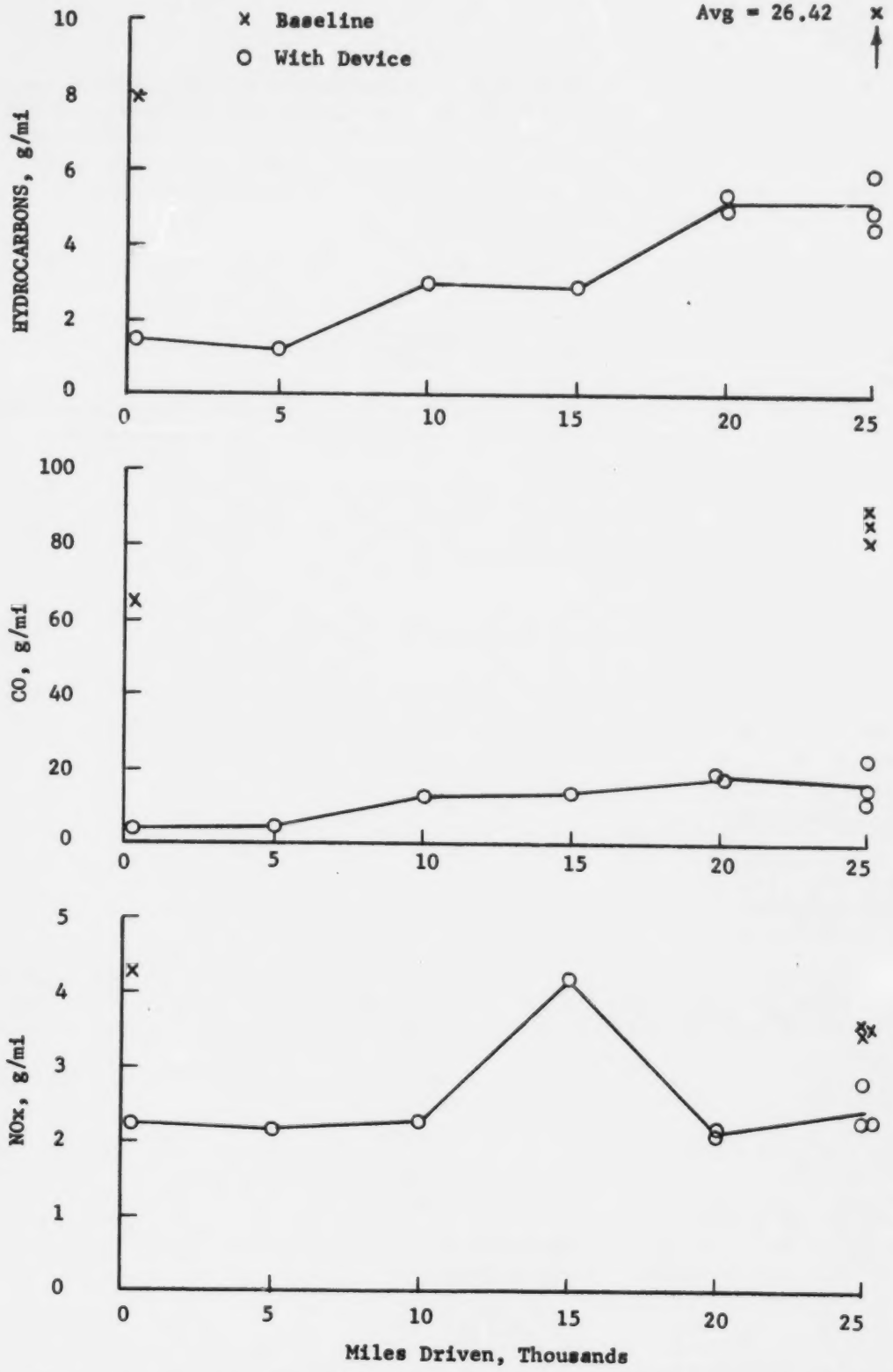


Figure 4-3. THE EFFECT OF MILEAGE ACCUMULATION ON THE CATALYST CONVERTER WITH VACUUM ADVANCE DISCONNECT (DEVICE 96, Car 22) ONE TANK OF LEADED FUEL ADDED AT 2500 MILE INTERVALS

Device 175. Ignition Timing Modification with Lean Idle Adjustment

The emission reductions achieved on Device 175 were:

EMISSION REDUCTION, PERCENT Ignition Timing Modification, Car 17		
	Zero Miles	25,000 Miles (Avg of 3 Tests)
HC	28	8
CO	18	-24
NOx	48	39

An emission reduction was maintained for the HC and NOx throughout the mileage accumulation period (Figure 4-4). NOx emission levels were still being reduced by 39% from baseline levels but HC was reduced only 8%. CO emission levels with the device installed were 24% greater than the baseline levels at 25,000 miles.

One reason for high CO levels measured at the 10, 15, and 20,000 mile points may have been due to a faulty choke operation (Figure 4-4). The car operated normally, even though the choke was partially closed most of the time before being repaired. The choke was repaired at 23,100 test miles. Following choke repair, it is not clear why the CO values during the 25,000 mile device tests averaged 24% above baseline levels.

Device 246. Exhaust Gas Recirculation with Vacuum Advance Disconnect

The percentage emission reduction results on Device 246 were:

EMISSION REDUCTION, PERCENT Device 246 - Car 18		
	Zero Miles	25,000 Miles Avg of 3 Tests
HC	46	- 3
CO	-8	-55
NOx	45	10

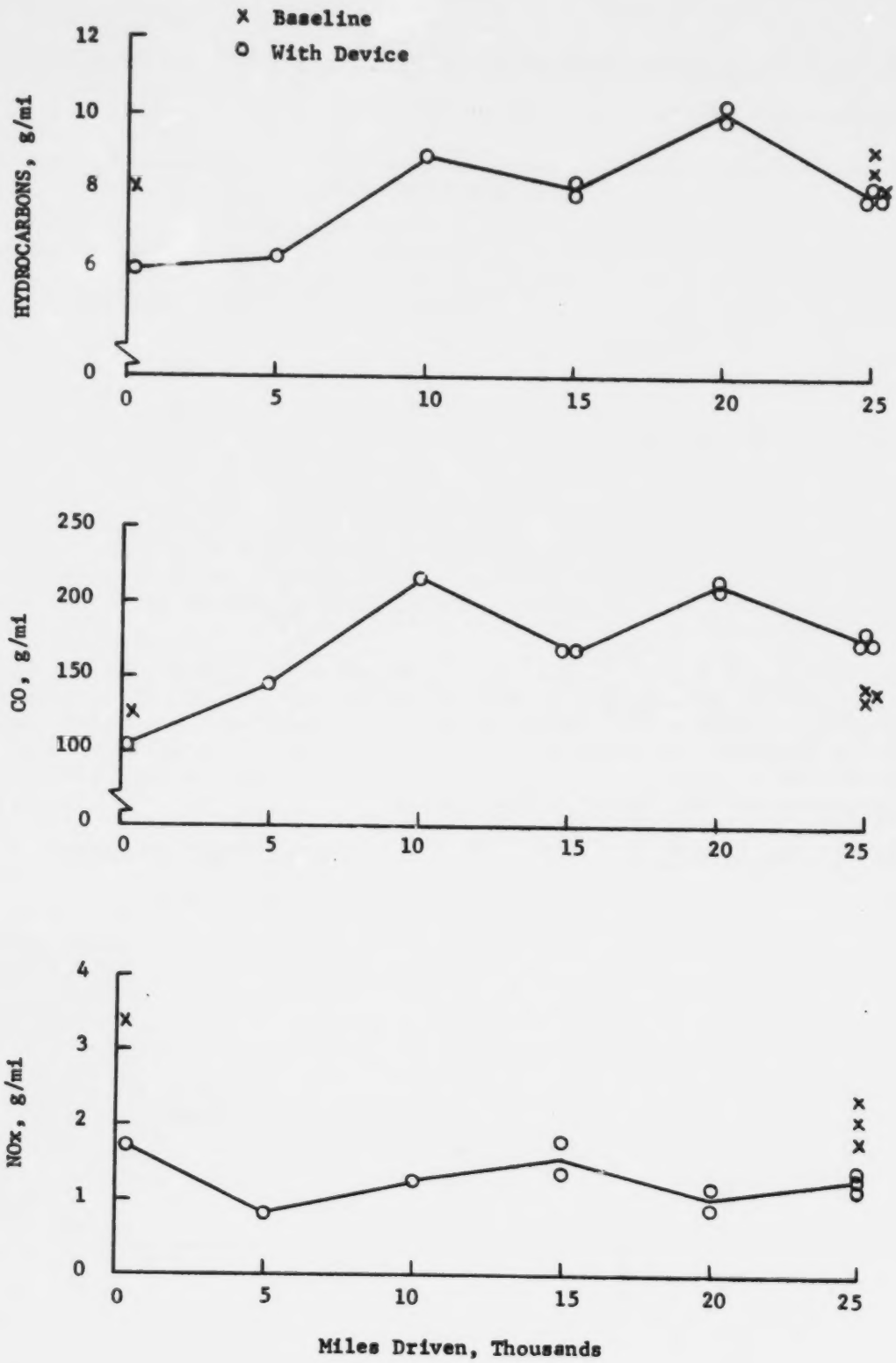


Figure 4-4. THE EFFECT OF MILEAGE ACCUMULATION ON THE IGNITION TIMING MODIFICATION SYSTEM WITH LEAN IDLE ADJUSTMENT (DEVICE 175, CAR 17)

Emission levels varied significantly (Figure 4-5). This may be attributable to continued choke malfunction which was found to be inoperative and repaired six times during mileage accumulation (Appendix A).

Hydrocarbon emission levels were approximately the same with or without the device at the 25,000 mile interval. Carbon monoxide emissions were 55% higher than baseline levels. It is possible that high CO levels may have been attributable to the choke problems.

NOx reduction was 45% at the zero mile interval and decreased to a 10% reduction from baseline at the 25,000 mile interval. The speed control switch for exhaust gas recirculation had to be replaced twice (see Section 4.3), and partial malfunction could explain the limited reductions of NOx at the end of the durability test.

Deterioration Factors - The deterioration factors for emission variation with mileage accumulation were not calculated because these would have been the deterioration factors for the vehicle-retrofit systems. Therefore, they would not be specifically representative for measuring the deterioration of the retrofit devices. These deterioration factors would have been particularly misleading for vehicles with significant performance deterioration.

4.2 FUEL AND OIL CONSUMPTION RESULTS

Table 4-2 presents the fuel and oil consumption during the durability tests. Fuel consumption was measured during the CVS tests at the 0 mile (baseline and device tests), and at each 5000 mile test interval. Fuel and oil consumption were also measured during the mileage accumulation phase with the device installed. There were no baseline fuel measurements made on the road.

Table 4-2 shows that in every case the CVS test fuel consumption in miles per gallon was lower than the average miles per gallon measured on the road during the previous 5000 mile interval.

In reviewing the fuel consumption data, it must be pointed out that test variability is high and that single fuel consumption tests were conducted at the 0, 5000, 10,000, and 15,000 mile interval. Duplicate tests were generally conducted at the 20,000 mile interval and triplicate tests were conducted at the 25,000 mile interval. A summary of the fuel and oil consumption is presented for each durability vehicle.

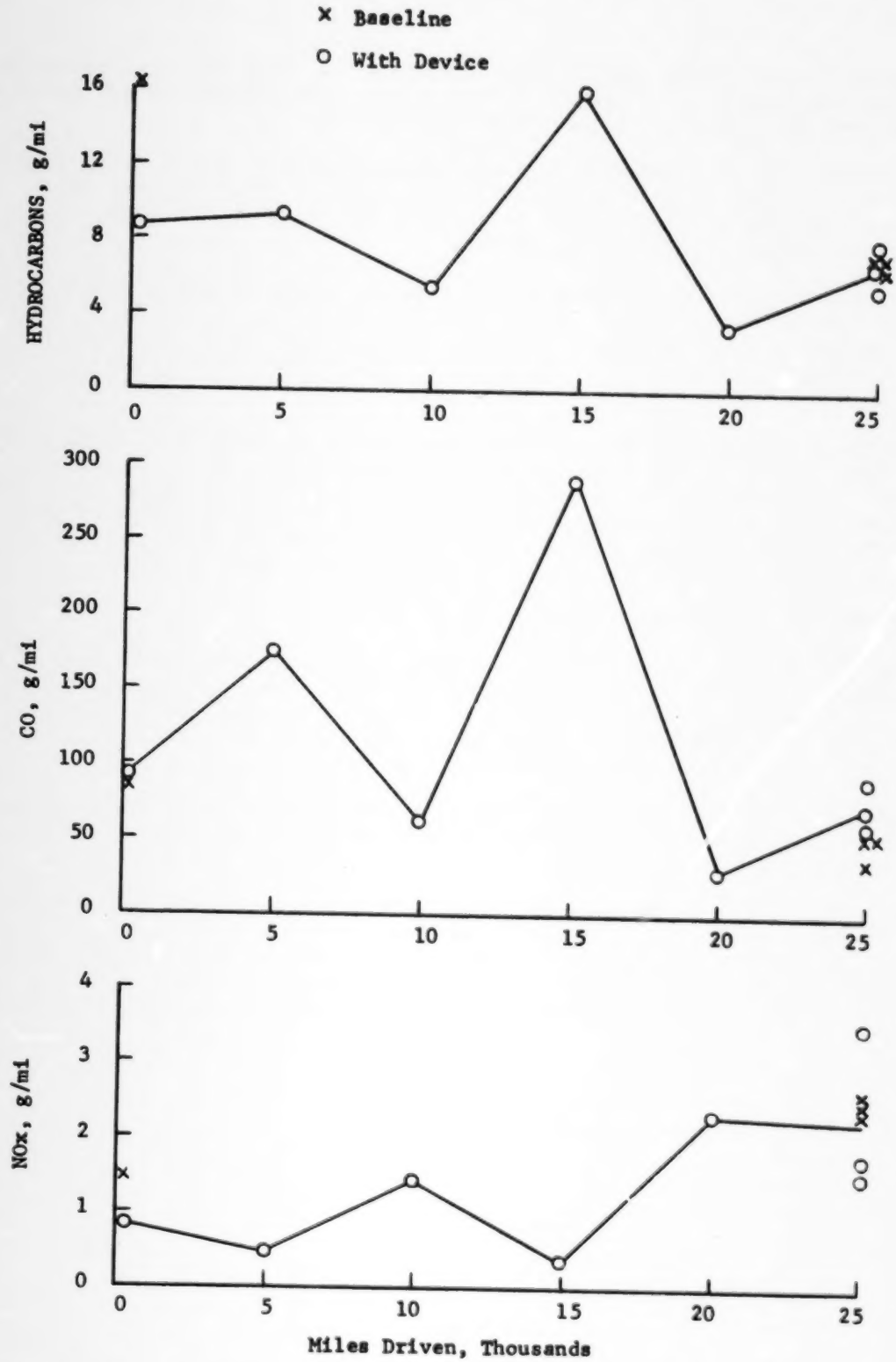


Figure 4-5. THE EFFECT OF MILEAGE ACCUMULATION ON THE EXHAUST GAS RECIRCULATION SYSTEM WITH VACUUM ADVANCE DISCONNECT (DEVICE 246, CAR 18)

Table 4-2. Fuel and Oil Mileage of Retrofit Durability Test Vehicles

Fuel Consumption (Miles/Gallon)

Device No.	Device Description	Vehicle No.	Test Condition (1)	Baseline, Zero Test Miles	Device, Zero Test Miles	Device, 5,000 Test Miles	Device, 10,000 Test Miles	Device, 15,000 Test Miles		Device, 20,000 Test Miles		Device, 25,000 Test Miles			Baseline, 25,000 Test Miles		
								Test 1	Test 2	Test 1	Test 2	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
1	Air Bleed to Intake Manifold	4	CVS	14.2	13.9	12.5	13.0	11.7	(2)	11.2	12.1	13.7	14.2	12.7	13.9	13.2	12.7
			ROAD			14.5	14.7	16.0		14.6		16.1					
			CVS (3,4)												14.2 (3)	14.2 (4)	
96	Catalyst Converter with Vacuum Advance Disconnect (Unleaded fuel, only)	21	CVS	12.3	11.0	11.2	10.1	11.5	(2)	9.2 (6)	10.4 (6)				11.0 (6)		
			ROAD			14.3	13.0	14.9									
			CVS (5)					9.2 (5)	9.2 (5)								
96	Catalyst Converter with Vacuum Advance Disconnect (Unleaded Fuel with One tank of Leaded Fuel at 2500 Mile Intervals)	22	CVS	14.5	14.0	11.2	12.7	13.2	(2)	12.3	(2)	12.5	12.7	15.1	12.1	9.7	11.5
			ROAD			14.1	15.1	15.5		15.5		15.7					
175	Ignition Timing Modification with Lean Idle Mixture	17	CVS	11.5	14.2	11.0	9.6	9.8	13.9	9.2	8.2	9.8	9.7	9.5	10.9	10.7	9.6
			ROAD			12.3	13.2	12.8		12.6		12.8					
246	Exhaust Gas Recirculation with Vacuum Advance Disconnect	18	CVS	10.5	11.6	9.9	12.3	12.3	(2)	11.2	(2)	11.4	11.4	12.7	13.4	12.1	13.4
			ROAD			13.8	14.9	12.9		16.0		15.7					

Oil Mileage (Miles/Quart)

1	Air Bleed to Intake	4	ROAD	(7)	(7)	1670	1250	1250		1250	625
96	Catalyst Converter with Vacuum Advance Disconnect (Unleaded fuel, only)	21	ROAD			625	625	380		120 (6)	
96	Catalyst Converter with Vacuum Advance Disconnect (Unleaded Fuel with One Tank of Leaded Fuel at 2500 Mile Intervals)	22	ROAD			560	720	610		1000	440
175	Ignition Timing Modification with Lean Idle Mixture	17	ROAD			330	260	370		320	230
246	Exhaust Gas Recirculation	18	ROAD			2500	2500	2500		1250	1250

NOTES:

(1) CVS - Fuel consumption measured during 1972 Federal Emission Test driving cycle
ROAD - Average fuel consumption and oil mileage measured on the durability test route over a 5999 mile interval. Oil mileage is based on oil added to crankcase between oil changes. Oil changes were conducted at each 5000 mile interval but this quantity was not included in oil mileage calculations.

(2) Replicate tests not conducted

(3) Replacement device installed and adjusted by developer

(4) Original durabilit, device reinstalled and adjusted by developer

(5) Diagnosis for possible carburetor malfunction. Test 1 - 16,764 miles, Test 2 - 16,878 miles

(6) Two device tests and one baseline test conducted at 20,000 miles. Mileage accumulation terminated shortly after 20,000 test miles

(7) Oil mileage not measured during zero mile tests

Device 1. Air Bleed to Intake Manifold - Car 4 - 1965 Chevrolet 327 CID

The average fuel consumption for each 5000 mile interval on the road ranged from 14.5 to 16.1 miles per gallon (mpg). The CVS fuel consumption tests with the device installed ranged from 11.2 to 14.2 mpg for all device tests. The baseline 0 mile test was 14.2 mpg and the 25,000 mile baseline averaged 13.3 mpg. The comparison of the average fuel consumption for the three replicate device tests at 25,000 test miles indicated a 4% saving from the baseline test results. This agrees with the results obtained on the retrofit test fleet. The oil mileage decreased from 1670 miles per quart in the first 5000 mile interval down to 625 miles per quart in the 20,000-25,000 mile interval. The vehicle had 111,066 miles at the 25,000 test mile interval.

Device 96. Catalyst Converter with Vacuum Advance Disconnect
(Unleaded fuel, Car 21, 1965 Chevrolet 327 CID)

The average fuel consumption for each 5000 mile interval on the road ranged from 13.0 to 14.9 mpg. The CVS fuel consumption with the device installed ranged from 9.2 to 11.5 mpg up to the 20,000 mile test interval. The zero mile test with the device installed was 11.0 mpg and was comparable to the device test fuel consumption up through the 15,000 mile test. At 16,800 test miles the CVS fuel consumption was 9.2 mpg which may have been the result of moderate vehicle degradation.

Oil mileage rates were 625 miles/quart for the first 10,000 miles of mileage accumulation. In the 15,000-20,000 mile interval the oil mileage decreased to 120 miles per quart indicating the vehicle engine was deteriorating at a very rapid rate (Table 4-2). Heavy smoke was being emitted from the tailpipe. Compression pressures also deteriorated with three cylinder pressures measuring between 30 and 70 psi at the 20,000 test mile interval (Appendix A). This vehicle terminated mileage accumulation shortly after the 20,000 mile interval. The odometer was 82,620 miles.

Device 96. Catalyst Converter with Vacuum Advance Disconnect
(Unleaded fuel with one tank of leaded fuel at 2500 mile intervals, 1965 Chevrolet 327 CID, Car 22)

The average fuel consumption for each 5000 mile interval on the road ranged from 14.1 to 15.7 mpg. The CVS fuel consumption with the device installed ranged from 11.2 to 15.1 through the 25,000 test mile interval. The zero mile device test measured 14.2 mpg and compares reasonably well with the zero mile baseline test of 14.5 mpg. The 25,000 mile baseline fuel consumption tests with the device installed were higher on the average than the baseline tests (13.4 mpg for the device versus 11.1 mpg for the baseline).

Oil mileage was approximately 560 miles per quart in the first 5000 miles of the durability tests and dropped to about 440 miles per quart in the last 5000 miles (Table 4-2). Cranking compression pressures all deteriorated slightly between the 0 and 25,000 mile interval, and one cylinder was very low at 40 psi (Appendix A). This deterioration pattern was not abnormal for a vehicle with 117,000 miles at the 25,000 mile interval.

Device 175. Ignition Timing Modification with Lean Idle Mixture
(1965 Ford 390 CID, Car 17)

The average fuel consumption for each 5000 mile interval on the road ranged from 12.3 to 12.8 mpg. The CVS fuel consumption tests with the device installed ranged from 8.2 to 14.2 mpg over all test intervals. The comparison of the average fuel consumption for the three replicate device test at 25,000 test miles indicated an 8% loss from the baseline test results. This agrees reasonably well with the 10% loss obtained on the retrofit test fleet.

The oil mileage was moderate throughout the 25,000 miles, and ranged from 260-330 miles per quart in the first 20,000 miles and decreased to 230 miles per quart during the last 5000 miles. This vehicle had 84,503 miles at the 25,000 mile test interval.

Device 246. Exhaust Gas Recirculation with Vacuum Advance Disconnect
(Car 18, 1961 Chevrolet, 283 CID)

The average fuel consumption for each 5000 mile interval on the road ranged from 12.9 to 16.0 miles per gallon. This large variation in road fuel consumption may have been caused by choke problems on this vehicle. The choke was repaired 6 times during the 25,000 test miles (Appendix A). The CVS fuel consumption device tests ranged from 9.9 to 12.7 mpg for all test intervals. The zero mile baseline was 10.5 mpg as compared to the 11.6 mpg for the 0 mile device test. The 25,000 mile baseline fuel consumption test averaged 13.3 mpg and can be compared to the device average of 11.8 mpg.

Oil mileage decreased from 2500 miles per quart in the first 15,000 miles down to 1250 miles per quart in the 15,000 to 25,000 mile interval. This vehicle had 108,000 miles at the end of 25,000 test miles.

4.3 EFFECT ON DEVICE AND VEHICLE OPERATION

This section will present the anomalies and problems connected with the operation of the retrofitted vehicles during the durability tests. The effects on device and vehicle operation are discussed in terms of driveability and safety, device reliability and vehicle reliability. The results of the final inspection are also included.

Driveability and Safety: During the durability tests, mileage accumulation was accomplished on a representative test route as described in Section 3.5. The drivers were non-technical personnel and were not trained to monitor retrofit device driveability type problems. However, the drivers maintained daily log data sheets which provided a checklist of vehicle maintenance type problems. If they suspected any anomalies of any kind, they were instructed to return to the OLI Anaheim Test Facility for corrective action by the OLI mechanic-technician. He in turn, recorded the vehicle and/or device problems. Appendix A presents a summary of these types of problems.

Overall, the drivers did not report driveability problems related to the device. Their only comments were vehicle related such as "low brake pedal, bald tire, and water leaks."

There were no device oriented safety problems reported by the durability test drivers. Car 21 which was equipped with the catalyst converter (Device 96) was terminated at 20,000 test miles due to an engine failure (see section on Vehicle Reliability). Converter temperatures were measured at 18,800 test miles and were 1200-1350°F as measured on the road during the freeway portion of the test route. This is not excessive and ~~should~~ present no safety problems to the vehicle or the occupants.

Device Reliability: No device anomalies were observed on the air bleed to the intake manifold (Device 1) retrofit system except for the installation problem discussed above (Section 4-1). The final inspection of Device 1 showed only a dirty air bleed filter. Inspection of the system revealed no other malfunctions of the control unit. Section 4-1 discusses the reasons why the device may not have achieved the desired emission reduction.

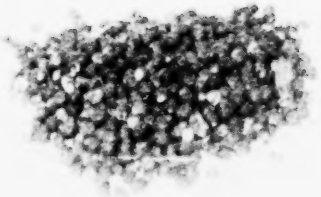
On the catalyst equipped vehicle (Device 96-Car 21) which used unleaded fuel one converter failed just after the 20,000 mile test. The catalyst converters were removed shortly after the 20,000 mile tests and the contents were weighed to determine the attrition. Eighty-seven percent of the catalyst was recovered from the left converter. No catalyst was recovered from the right converter due to a failure of the catalyst retaining screen. Photographs of the retaining screen failure are presented in Figure 4-6. Examination of the failed device indicated that the device may have been operating at excessive temperatures (greater than 1500°F) just prior to failures causing the retaining screen to burn through and fail. It was operating at normal temperature at 18,800 test miles. The device was returned to the developer for examination (no results were received from the developer at the time of this report).

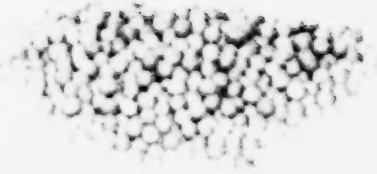
Because of the deterioration of the vehicle engine and the loss of catalyst in the right converter, the vehicle mileage accumulation was then terminated. At this time the vehicle had a total odometer mileage of 82,620 miles.

Figure 4-6 shows a photograph of the new and the used catalyst from Car 21 recovered after the removal of the left converter. The catalyst used in the durability tests appeared to have an oil type residue on the outer surface of the catalyst pellets.

After the 25,000 mile tests on Car 22 (the vehicle which had a full tank of leaded fuel every 2,500 miles), the recovery of the catalyst from the right converter was 91.6 percent while 80.0 percent was recovered from the left converter. On Car 22 (Catalyst-Device 96) the air bypass valve was replaced at 8700 and 12,200 test miles (Appendix A). This valve provides overtemperature protection in the converter by diverting the injected pump air to atmosphere. The valve failure was apparently not caused by the converter, but appeared to be a mechanical malfunction of the valve itself.

For the ignition timing modification system (Device 175) the developer tested the unit operation on the vehicle following the 25,000 mile device tests, and verified that the device was operating the distributor advance in the specified manner at the applicable speeds. Subsequently, the device was inspected by the developer which revealed that two diodes were malfunctioning in the electronic circuit. It was possible that this failure could have been caused by the vehicle alternator failure which occurred at 23,600 test miles. If the





alternator failure was the cause of the device malfunction, then the device should be designed to prevent such failures in the event of vehicle electrical failures (see Vehicle Reliability below).

The EGR device speed control switch was replaced on Car 18 (Device 246) twice during mileage accumulation. The first replacement was necessary because it was damaged along with the speedometer cable at a car wash facility (the speedometer cable was hanging below the car and snagged on the equipment). The first replacement became inoperative and the speed switch had to be replaced again at 9800 test miles (Appendix A).

Inspection of the exhaust gas recirculation system (Device 246) control valves and connecting tubing revealed only a light thin film of carbonaceous appearing material on the inner surfaces.

Vehicle Reliability: On the air bleed system (Device 1, Car 4), the plugging of the blowby control inlet to the carburetor base was definitely a vehicle oriented problem. This was not an abnormal condition for a 1965 model car with 111,000 (Section 4.1 presents a detailed discussion of this problem).

The catalyst systems (Device 96) on cars 21 and 22 did not appear to have any major effects on vehicle operation. As discussed in Section 4.1 the device on Car 21 failed shortly after 20,000 test miles which may have been caused by the high oil consumption rate.

At the 23,500 mile test point the vehicle alternator diodes failed on Car 17 which was equipped with the ignition timing modification system (Device 175). The alternator was repaired and the vehicle continued to accumulate mileage. Coincidentally the vehicle developed moderate hesitation at heavy engine loads which was particularly noticeable when accelerating onto the freeway. The vehicle operated normally at cruising conditions. The malfunction was reported to the developer and his instructions were to continue mileage accumulation through 25,000 miles.

Following the 25,000 mile device and baseline emission tests, a diagnosis was conducted to determine the cause for the hesitation under heavy loads. The car was operated at 50 mph on the dyno to simulate heavy road loads (uphill). Moderate plug misfire was observed. The device was removed and the vehicle was again operated on the dynamometer to simulate heavy loads. No plug misfire was evident as measured by the ignition analyzer scope. Secondary coil voltages were measured at several speeds both with and without the device installed. (See Appendix A.)

The diagnosis showed that the misfire was caused by the device at moderate engine loads (see Device Reliability section above).

The exhaust gas recirculation system (Device 246, Car 18) caused no effects on the operation of the car. However, as discussed in Section 4.1, the choke malfunctioned and was repaired six times during the 25,000 mile test interval.

APPENDIX A

DEVICE AND VEHICLE REPAIR AND MAINTENANCE

APPENDIX A

Device 1 Car 23 - Air Bleed to Intake Manifold

Test Miles	
1998	Starter solenoid replaced
10047	Engine Stalls. Idle rpm increased
12593	Minor tuneup, choke assembly changed
21427	Carburetor cleaned (See text)
21878	Fuel pump replaced

Device 96 Car 21 - Catalyst Converter With Vacuum Advance Disconnect
No Lead Fuel

Test Miles	
383	Installed fuel filter
2567	Loose exhaust muffler repaired
3442	Front end alignment - replace front shock absorbers - replace upper bushings.
5300	Tailpipe repaired
6794	Pyrometer installed by developer to monitor the catalyst bed temperature and verify operation of by-pass valve alarm
7176	Loose exhaust pipe coupling to the exhaust manifold - repaired
7925	Turn signal flasher replaced
10925	Broken motor mount - replaced
12000	Minor tuneup of vehicle - oil change and chassis lube
16562	Bypass valve control circuit malfunction. Valve provided pump air to converter continuously through 20,000 miles as directed by developer.
16878	Converters removed for CVS baseline emissions
16904	Converters replaced
18862	Brakes repaired and adjusted
20036	Durability tests terminated (See text)

Cranking Compression Pressures psi

Cylinder	Zero Miles	20,000 Miles
1	175	155
2	180	160
3	170	155
4	175	145
5	185	70
6	170	90
7	170	30
8	170	125

Catalyst Device Temperatures
at 18,800 Test Miles

Speed mph	Location	Temperature, °F
60	Anaheim	1200
65	Yorba Linda	1300
65	Corona	1250
65	Riverside	1350
60	San Bernardino	1300

Device 96 Car 22 - Catalyst Converter With Vacuum Advance Disconnect
(One tank of leaded fuel every 2500 miles)

Test Miles	
136	Wheels balanced
1266	Exhaust manifold-gaskets replaced, check valve replaced
	Heat riser valve frozen - repaired
2659	Right front fender damaged at car wash
3213	New tires installed
4492	Valve gasket leaks oil
5670	Speedometer malfunction - repaired
5990	Right front wheel bearings repaired
8688	Air valve (solenoid) replaced - leaking
12099	12,000 mile tuneup
12223	Replaced air valve
15500	Air bypass valve control circuit malfunction. Valve provide pump air to converter continuously through 25,000 miles as directed by developer.

Cranking Compression Pressures, psi

Cylinder	0 Mile	25,000 Miles
1	180	180
2	160	155
3	180	150
4	175	150
5	175	40
6	165	170
7	160	165
8	170	160

Attrition Rate of Catalyst
Right Canister - 91.5 percent recovered
Left Canister - 80.0 percent recovered

Device 175 Car 17 - Ignition Timing Modification With Lean Idle Adjustments

Test Miles	
905	Engine stalled due to heavy rain
3058	Vacuum leak to intake manifold - repaired
6131	Exhaust system leak - repaired
10656	Emergency brake light burned-out - repaired
12000	Minor tuneup; plugs, points, and condenser
19671	Air conditioning and power steering belts replaced
19954	Brakes adjusted
23629	Alternator replaced due to diode failure
	Oil residue removed from choke oven
	Plugged heat riser repaired
	High speed idle adjusted
25000	Cylinder compression test

#1, 150 psi	#5, 145 psi
#2, 135 psi	#6, 135 psi
#3, 145 psi	#7, 135 psi
#4, 120 psi	#8, 105 psi

25000 Coil available voltage measurement (kilovolts)

RPM (N)	With Device	Without Device
1000	29	32
2000	26	32
2500	18	32
3000	16	32

Device 246 Car 18 - Exhaust Gas Recirculation With Vacuum Advance Disconnect

Test Miles	
322	Difficult vehicle starting - choke malfunction repaired
521	Speedometer cable broken - repaired
	Valve cover gasket leaked - repaired
882	Speedometer cable broken again - repaired
	Gasoline leak - repaired
966	Replaced speed switch which was damaged at the time speedometer cable was damaged and not detected. Replaced nylon gear drive for speedometer cable
1638	Speedometer not operable - repaired
3437	Adjusted choke spring and unloader
42[illegible]5	EGR connection or exhaust pipe loose - repaired
9794	Replaced speed switch. Choke assembly needed adjusting - replaced air filter
10697	Replaced choke heat tube
12000	Minor tuneup; points, plugs, and condenser
12448	Device speed control switch replaced
15680	Inoperative choke - engine stall
25000	Choke heat tube and carburetor choke assembly replaced
	Exhaust heat riser valve replaced

The developer recommends cleaning the EGR valve every six (6) months. At that time the solenoid vacuum valve filter should be inspected and cleaned/replaced as necessary. However, no exhaust gas flow restrictions were experienced with the EGR valve during the mileage accumulation. Inspection of the valve at 25,000 miles revealed only a very thin dark film of carbonaceous appearing material inside the valve.